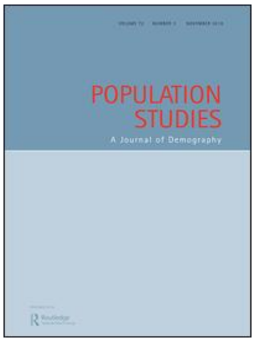

Population Studies
A Journal of Demography

ISSN: 0032-4728 (Print) 1477-4747 (Online) Journal homepage: https://www.tandfonline.com/loi/rpst20

All-time low period fertility in Finland: Demographic drivers, tempo effects, and cohort implications

Julia Hellstrand, Jessica Nisén & Mikko Myrskylä

To cite this article: Julia Hellstrand, Jessica Nisén & Mikko Myrskylä (2020): All-time low period fertility in Finland: Demographic drivers, tempo effects, and cohort implications, Population Studies, DOI: 10.1080/00324728.2020.1750677

To link to this article: https://doi.org/10.1080/00324728.2020.1750677

Published online: 12 May 2020.

Population Studies, 2020
https://doi.org/10.1080/00324728.2020.1750677

All-time low period fertility in Finland: Demographic drivers, tempo effects, and cohort implications

Julia Hellstrand[1,2], Jessica Nisén[1,2] and Mikko Myrskylä[1,2,3]
[1]Max Planck Institute for Demographic Research, [2]University of Helsinki, [3]London School of Economics and Political Science

The ongoing period fertility decline in the Nordic countries is particularly strong in Finland, where the total fertility rate (TFR) reached an all-time low of 1.41 in 2018. We analyse the decrease in Finland's TFR in 2010–17, and assess its consequences for cohort fertility using complementary approaches. Decomposition of this fertility decline shows that first births and women aged <30 are making the largest contributions. However, women aged 30–39 are also, for the first time in decades, experiencing a sustained fertility decline. Tempo adjustments to the TFR suggest that quantum change is part of the decline. Several forecasting methods indicate that cohort fertility is likely to decline from the long-lasting level of 1.85–1.95 to 1.75 or lower among women born in the mid-1980s. Without an exceptionally strong recovery in fertility, Finnish cohort fertility is likely to decline to levels currently observed among countries with very low fertility.

Keywords: period TFR; cohort fertility; fertility postponement; forecasting; non-parametric approach; Finland; Nordic fertility regime

[Submitted July 2019; Final version accepted March 2020]

Introduction

In recent decades, family demographic research has shown that Finland and the other Nordic countries exhibit relatively high and stable cohort fertility (Frejka 2008, 2017; Andersson et al. 2009; Myrskylä et al. 2013; Zeman et al. 2018; Jalovaara et al. 2019). This trend has been partly attributed to the institutional and socio-cultural settings of these countries, which strongly promote gender equality in the labour market and the family (Ellingsæter and Leira 2006; Rønsen and Skrede 2010). As the Nordic countries all have similar policies aimed at promoting work–family reconciliation among parents, scholars have argued that these policies contribute to a common Nordic fertility regime with very similar period and cohort fertility patterns (Andersson 2004; Neyer et al. 2006; Andersson et al. 2009). These patterns include fertility postponement and, unlike in other countries, strong recuperation of births at older ages. Thus, in these countries, cohort fertility has remained stable at around two children per woman, while women's labour market participation has remained high.

Since 2010, total fertility has been decreasing across the Nordic countries (Finland, Norway, Iceland, Denmark, and Sweden) (Comolli et al. 2019). The average total fertility rate (TFR) across these countries decreased from 1.97 to 1.74 in the five years from 2010 to 2015; and the decrease has been strongest in Finland, where the TFR declined from 1.87 in 2010 to an all-time low of 1.41 in 2018 (Official Statistics of Finland 2019). Birth rates in the early 2010s have been studied in Finland (Comolli 2018) and across the Nordic countries (Comolli et al. 2019), but the accelerating decrease during the most recent years, specifically in Finland, has not yet been studied in detail despite considerable public attention.

The current TFR in Finland is well below the 2016 European Union (EU) average of 1.60, far below the current Nordic country average (OECD 2019), and close to the all-time lowest TFR recorded in the Nordic countries (1.38 in Denmark in 1983; Andersson 2004). During the 1960s, fertility fell rapidly, and period TFRs were comparatively low in all Nordic countries by 1980, as higher-order births decreased and fertility shifted to older ages. It is unlikely that similar factors can explain decreasing fertility levels today, because most variation in fertility in Europe is currently driven by variation in first and second births (Frejka 2008; Zeman et al. 2018). However, the demographic determinants driving these contemporary fertility declines are unknown, as no existing studies have detailed their components. Previous analyses of birth risks in the Nordic countries after the recent recession (Comolli et al. 2019) are based on data only up to 2014 for Finland and, unlike our study, they did not adopt a tempo–quantum or forecasting perspective on fertility developments.

Fluctuations in period fertility do not necessarily affect the completed fertility of cohorts, since period-based measures such as the TFR are sensitive to shifts in the timing of childbirth (Bongaarts and Feeney 1998), and period rates tend to underestimate completed fertility when births are being postponed (Myrskylä et al. 2013). Thus, a decrease in the TFR can be driven by either delayed childbearing or lower childbearing, or a combination of both. The recent decrease in period fertility in Finland raises the question of to what extent this decrease will be reflected in the total number of children women have, that is, the fertility quantum of cohorts of Finnish women currently of childbearing age. While the most recent cohort fertility forecast for Finland did not indicate that the country's fertility quantum was decreasing (Myrskylä et al. 2013; Schmertmann et al. 2014), the rapid decline in period fertility in recent years suggests that it is. Updated forecasts are therefore required.

The aim of this study is to investigate the recent rapid decline in total fertility in Finland, and its potential effects on cohort fertility. Our main research questions are as follows:

(1) Which age groups and parities have contributed to the period fertility decline in 2010–17?
(2) What would the TFR in this period have been in the absence of fertility postponement?
(3) Are women born after the early 1970s likely to have fewer children than earlier cohorts; and, if so, how many fewer?

Answering these questions is important because a substantial decrease in cohort fertility in Finland would call into question whether Finnish fertility conforms to the idea of a Nordic fertility regime. This would indicate that even a family-friendly country, such as Finland, is not spared from the challenges of low fertility seen in many other European and East Asian countries.

To address questions (1) and (2), we use standard demographic decompositions and tempo adjustments. To address question (3), we use existing parametric and model-based approaches to estimate completed cohort fertility rates (CFRs), and a novel non-parametric approach to assess possible recuperation paths for cohorts who have postponed childbearing. Each of the forecasting methods is based on different assumptions: from freezing the most recent age-specific rates and extrapolating recent trends, to using prior demographic data, both with and without strict modelling assumptions, to obtain likely fertility developments. Consequently, we produce cohort fertility forecasts that are not restricted to one method only. Our study is the first to apply the non-parametric approach in the study of cohort fertility.

Fertility in Finland compared with other high-income countries

Finland is often positioned as sitting within the established idea of a Nordic fertility regime—a context of high and stable fertility combined with high support for working mothers and consequently high labour force participation and childcare enrolment rates—as it shares many similar characteristics in family polices and childbearing trends with other Nordic countries (Andersson et al. 2009). The idea of a Nordic fertility regime is widespread in the literature (e.g. Rønsen and Skrede 2010; Jónsson 2017; Merz and Liefbroer 2018). However, Finland can be seen as an outlier in some respects. Cohort fertility close to replacement level in Denmark, Sweden, and Norway is the result of a strong two-child norm where most women enter motherhood (Frejka 2008; Zeman et al. 2018). On the contrary, ultimate childlessness in Finland is among the highest in Europe (Neyer et al. 2006; Kreyenfeld and Konietzka 2017). For instance, 20 per cent of women born around 1970 were still childless at age 40 (Jalovaara et al. 2019). Also in Finland, remaining ultimately childless usually results from the process of postponing childbearing until it becomes too late to have a child, rather than being an active choice (Miettinen 2010). Ultimate childlessness strongly relates to union histories: most childless Finns at the end of their reproductive age have experienced unstable or non-existent spells of co-residential partnership (Jalovaara and Fasang 2017), and the likelihood of remaining childless decreases as marriage or partnership length increases (Saarela and Skirbekk 2019). Cohort fertility is still fairly close to replacement level in Finland, although at a slightly lower level than in the rest of the Nordic countries, due to high rates of continued childbearing among mothers (Eurostat 2019; Jalovaara et al. 2019). Cohort fertility is highest for women who start their childbearing at an early age and decreases with increasing age at first birth (Roustaei et al. 2019). In Finland, it has declined slightly among the most recent cohorts: among women born in the 1960s, the CFR fell from nearly 2.0 to 1.9.

The dominant trend in cohort fertility over the 1940–73 birth cohorts in other high-income countries has been a decline (Figure 1), and this decline has been more pronounced in Central, Eastern, and Southern Europe and in East Asia compared with Western and Northern Europe and the United States (US). The former group has experienced completed fertility below 1.75, which is the level that can be viewed as a threshold between low and 'very low' cohort fertility (Zeman et al. 2018). These two distinct fertility regimes can also be observed in recent period fertility trends (Rindfuss et al. 2016). In the last few decades, countries such as Spain, Germany, and Japan have reported 'lowest-low' fertility, with total fertility below 1.3 (Kohler et al. 2002; Goldstein et al. 2009), while period fertility in Nordic and English-speaking countries has remained fairly stable or recovered slightly (Anderson and Kohler 2015). However, these two distinct fertility regimes have started to converge in the most recent years (Figure 2). Many countries with relatively high fertility reached a peak in their TFR around 2010 and have subsequently experienced declines of varying speeds, while TFRs in low-fertility countries, and in particular in Eastern Europe, are recovering substantially. Amid these trends, the rapid fertility decline in Finland and the other Nordic countries stands out. A significant decline in cohort fertility as well would place Finland among the group of countries with very low fertility (currently found in Central, Eastern, and Southern Europe), rather than among the countries with current relatively high fertility (in Northern and Western Europe).

Data and methods

Data

In our study, we use aggregated data from the Human Fertility Database (HFD). The HFD is a source of high-quality fertility data, and is based on a collaboration between the Max Planck Institute for Demographic Research and the Vienna Institute of Demography. For the analysis of period fertility, we use data containing both unconditional and conditional fertility rates by calendar year, age, and birth order, from the year 1960 onwards. The conditional fertility rates control for age and parity (e.g. second births relate to women of parity one only), whereas the unconditional fertility rates control only for age. For cohort fertility estimation, we use period fertility rates by calendar year, age reached during the year, and birth cohort for all countries with data available in the HFD database from the 1900 birth cohort onwards. The published time series of HFD rates from Finland at the time of writing (14 February 2019) ended in 2015, but we were kindly provided with preliminary data for the years 2016–17 (Jasilioniene, personal communication).

Methods

Our analyses are based on four different approaches, which examine the decreasing period fertility in Finland independently of each other and from different angles. First, time trends in fertility are described by five-year age group, and the drop in period fertility between 2010 and 2017 is decomposed into additive age and parity contributions. We decompose the differences in the age- and parity-adjusted TFR (TFRp), which is computed from conditional age- and parity-specific fertility rates using the stepwise replacement method (Andreev et al. 2002; Andreev and Shkolnikov 2012). In addition to adjusting for population age structure, the TFRp adjusts for differences in the parity composition of the female population. Therefore, the TFRp may differ slightly from the conventional TFR.

Second, we use the tempo-adjusted TFR (Bongaarts and Feeney 1998) to analyse the impact of changes in the timing of childbearing on the recent fertility decline. A decrease in the observed TFR can be attributed to increasing tempo effects if there is no decrease in the tempo-adjusted TFR, while quantum changes can be held responsible if the observed and tempo-adjusted TFRs show similar decreases. Since the latest year's observation is lost in the Bongaarts–Feeney adjustment, we calculate a crude estimate following Goldstein et al. (2009) to replace the lost observation (Appendix 1).

Third, cohort fertility is forecasted to address the question of whether cohorts currently of childbearing age will ultimately have fewer children than earlier cohorts; and, if so, how many fewer. The tempo adjustments decompose changes in period fertility into tempo and quantum components, whereas the

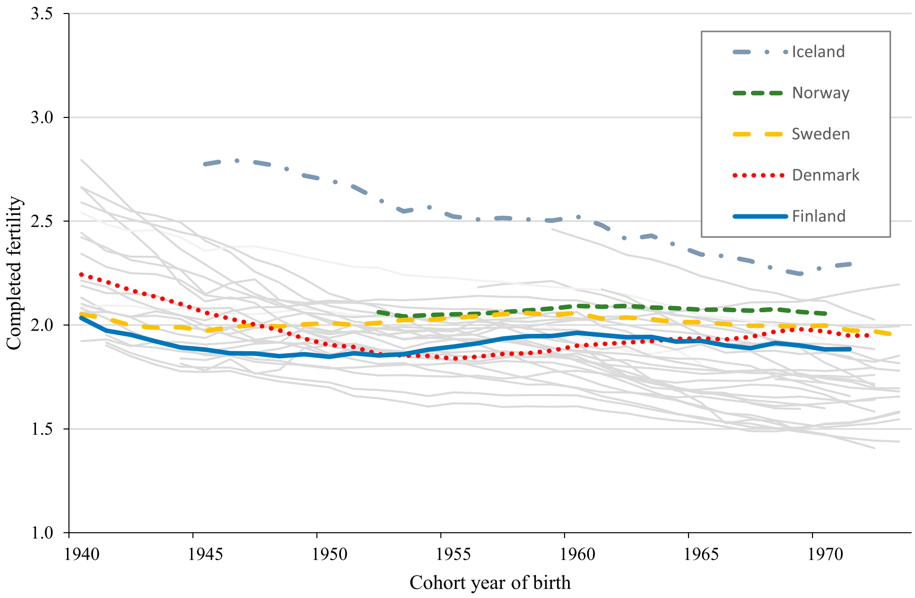

Figure 1 Completed fertility of women born in 1940–73: all HFD countries, with Nordic countries highlighted
Source: Human Fertility Database: Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at www.humanfertility.org (accessed 28 November 2019).

forecasting methods estimate cohort fertility and may detect pure fertility quantum changes. Cohort fertility forecasting is accomplished by estimating the remaining unobserved fertility rates for cohorts with incomplete fertility schedules. We forecast cohort fertility using three different methods: the simple freeze rate method, the five-year extrapolation method (Myrskylä et al. 2013), and a Bayesian method (Schmertmann et al. 2014). Recent evaluations of the forecasting performance of a large number of methods for cohort fertility completion have suggested that the five-year extrapolation method (Myrskylä et al. 2013) and the Bayesian forecasting method (Schmertmann et al. 2014) are among the most accurate (Bohk-Ewald et al. 2018).

The freeze rate method freezes the latest observed age-specific fertility rates into the future. Hence, the

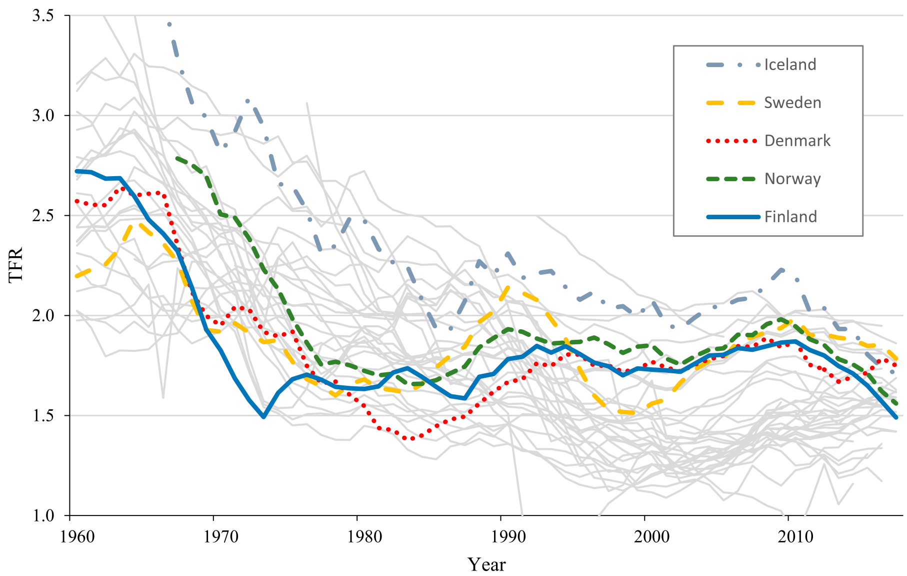

Figure 2 Total fertility rate (TFR), 1960–2017: all HFD countries, with Nordic countries highlighted
Source: As for Figure 1, plus Eurostat 2019 (for TFR in 2017 in Denmark, in 2016–17 in Finland and Iceland, and in 2015–17 in Norway).

method borrows the most recent year's rates and applies them to cohorts with unobserved fertility rates. This approach is appropriate when fertility is stable, but can underestimate cohort fertility when fertility is shifting to older ages. The five-year extrapolation method estimates the trends in age-specific fertility over the past five years, extrapolates the trends five years into the future, and then freezes these rates (Myrskylä et al. 2013). Extrapolation of trends is appropriate when fertility developments are stable, but can give misleading estimates in times of trend changes.

The Bayesian forecasting method (Schmertmann et al. 2014) produces a probabilistic forecast by combining prior demographic information about plausible age patterns and time trends in fertility, and extrapolating fertility rates over both time and age into the future (Appendix 2). The method produces uncertainty estimates, and no explicit choice between the freeze rate approach and the five-year extrapolation approach needs to be made in the Bayesian framework. The prior distribution for typical fertility rates is constructed based on three basic categories of prior information: cohort schedule shapes, time-series freeze rates, and time-series freeze slopes. The cohort category of prior information describes typical shapes of cohort schedules and the time-series categories of prior information describe how smooth a time series is likely to be at a given age based on historical data. These categories of prior information are then combined to determine likely or unlikely fertility surfaces, that is, fertility rates over the cohort's year of birth (x-axis) and age (y-axis). The general features of past rate surfaces are assumed to persist into the future. Historically unlikely fertility surfaces with age patterns in cohort fertility schedules that differ from patterns in historical data, and whose patterns in time series of age-specific rates differ from the corresponding series in historical data, have high penalties, and are therefore assigned lower prior probabilities. Thus, the Bayesian method produces forecasts in which both time trends and cohort schedules are demographically feasible.

Fourth, we use a novel non-parametric forecasting approach to assess—without making modelling assumptions as in the Bayesian method—whether historical recorded fertility includes recuperation paths that would prevent Finnish cohort fertility from declining strongly. While the Bayesian method restricts trends in age-specific fertility rates to being relatively smooth, the non-parametric approach does not make similar restrictions and therefore allows estimation of cohort fertility in circumstances of abrupt change. The non-parametric approach is based on the work of Keyfitz (1985, 1989), Denton et al. (2005), and Dudel (2015), but is modified to fit our purpose of estimating possible fertility recuperation paths for older cohorts and their consequences for completed fertility. With HFD data we use this approach to calculate, for a cohort with observed age-specific fertility rates up to age x, the universe of fertility changes for ages above x observed in the past, and add these changes to the most recent year's fertility rates. The non-parametric approach makes use of HFD data to measure fertility recuperations only at older ages, while the Bayesian method uses cohort fertility schedules and time-series trends in fertility rates at all ages.

As an example, consider the cohort born in 1980, whose fertility rates are observed up to age 37 in 2017. The rate at age 38 is observed in 2018, and the final rate at age 44 is observed in 2024. To complete the fertility schedule of this cohort, we calculate starting in 2017 the change one year ahead, the change two years ahead, and so on, up to the change seven years ahead. We then sum up these changes to form a possible recuperation path for this cohort. To derive a universe of possible recuperation paths for each cohort born between 1975 and 1987, we use all HFD data from 1975 onwards. This results in a total of 910 possible fertility recuperation schedules for the cohort born in 1987, and 1,342 possible schedules for the cohort born in 1975. The smaller number of possible recuperation schedules for the later-born cohorts results from the fact that they will reach the end of their reproductive age in later years than earlier-born cohorts, and therefore need longer time series of past data. For each cohort, we resample from the universe of fertility recuperation schedules with replacement (10,000 samples) to derive non-parametrically a probabilistic distribution of potential future fertility trajectories. We also repeat the same procedure but restrict the possible recuperation schedules to those observed in the Nordic countries, because the Nordic patterns may better reflect the realm of recuperation possibilities for Finland.

Results

Age-specific fertility developments, 1960–2017

Figure 3 shows the development in period fertility rates by five-year age group in Finland in 1960–2017. We provide a longer time period on age-specific fertility developments and data for more

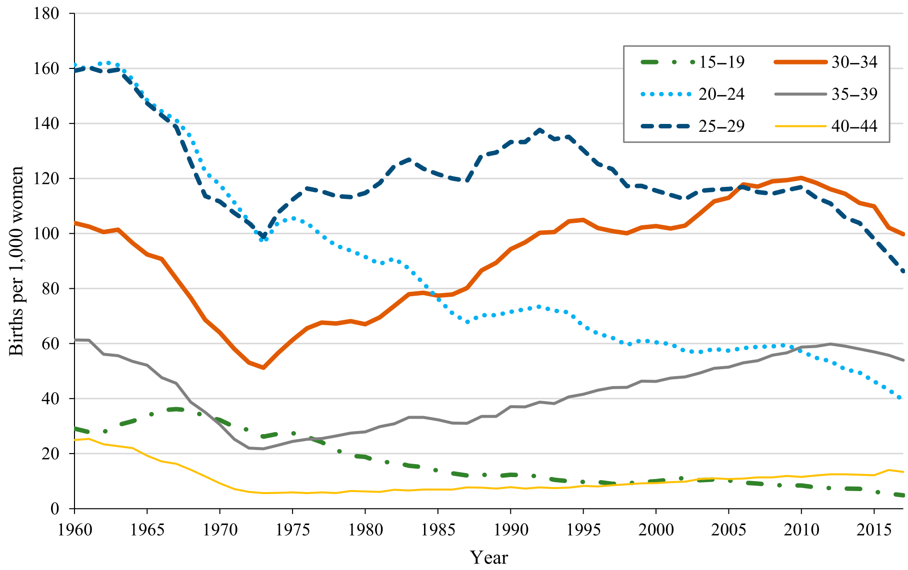

Figure 3 Age-specific fertility rates, Finland, 1960–2017
Source: As for Figure 1.

recent years compared with results published elsewhere (e.g. Official Statistics of Finland (2015); Roustaei et al. (2019)). Since the 1970s, the timing of childbirth has been shifting to older ages. Since the rapid period fertility decline in the 1960s that affected almost every age group, fertility rates at ages below 25 have continued to decrease, while fertility rates at ages 30+ have been increasing. The fertility rate among 25–29-year-olds peaked in the early 1990s, at a rate of nearly 140 live births per 1,000 women, while the corresponding rate for 30–34-year-olds was around 100. In the past, 20–24-year-old women had children at a higher intensity than 35–39-year-old women. But since 2010, this pattern has reversed and fertility has become more concentrated at older ages. Notably, since 2010, there have been declines in fertility in nearly all age groups: the childbearing intensity of women below age 30

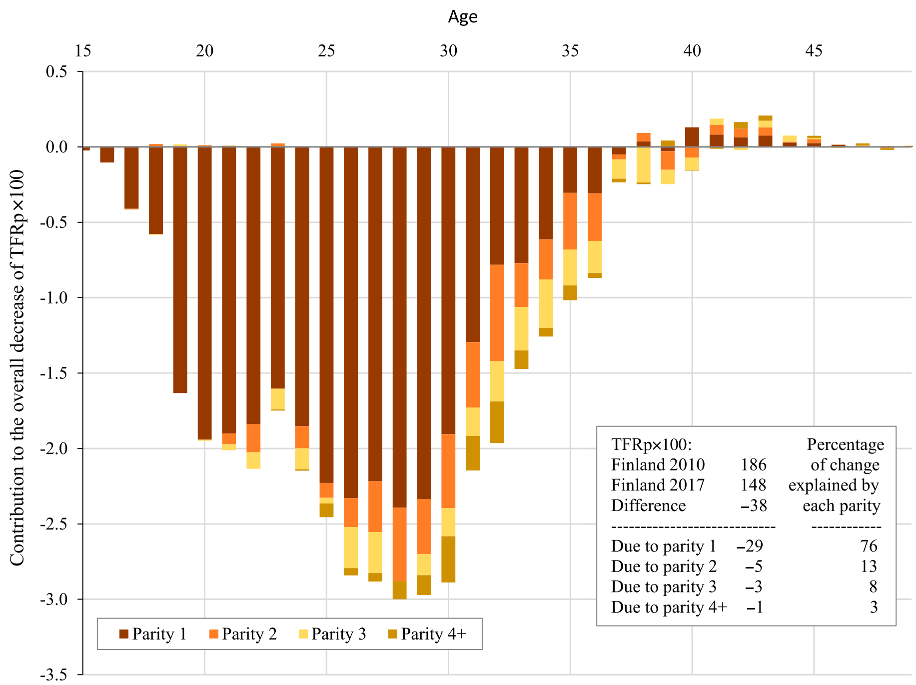

Figure 4 Decomposition of the 2010–17 decrease in the TFRp by age and parity, Finland
Source: Authors' calculations based on the Human Fertility Database.

has been reducing even more rapidly than in the past, while the fertility rates of women aged 30–39 have been decreasing for the first time since the early 1970s. The downward trend among women at ages 30–39 is suggestive of a quantum effect, since women who postpone childbearing to later reproductive ages are at higher risk of experiencing infertility.

Contributions of age and parity to the decrease in period fertility, 2010–17

Figure 4 shows the decomposition of the decrease in the TFRp between 2010 and 2017 by age and parity. The TFRp, which is adjusted for both the age and parity composition of the female population, fell from 1.86 in 2010 to 1.48 in 2017. The greatest contributions to this steep decline came from the decreasing childbearing intensity of women in their late 20s, although women at nearly every age contributed to this trend. Women close to the end of their reproductive years were the only ones who contributed positively to fertility change, albeit very modestly. Birth order decomposition shows that the contributions produced by the decreasing intensity of first births accounted for more than 75 per cent of the fall in period fertility. This decrease was not only pronounced among the youngest women but also among women in their early 30s. Changes in second and third births accounted for 21 per cent of the total decline in fertility while higher-order births played a negligible role in explaining the fertility decline. The changes in first birth intensity imply that the share of young childless women has increased: of the women in the 25–29 age group, 64 per cent were childless in 2010 (Official Statistics of Finland 2010) and 69 per cent were childless in 2017. Similarly, in the 30–34 age group, the childless share rose from 37 per cent in 2010 to 41 per cent in 2017.

Tempo-adjusted TFR, 1990–2017

Figure 5 shows the observed and tempo-adjusted TFR and the mean age at childbearing (MAC) in Finland in the period 1990–2017, by birth order and for all birth orders combined. The MAC for all births was 30.9 years in 2017, which represents an increase of two years since 1990 (Figure 5(a)). The tempo-adjusted TFR was higher than the observed TFR in every year, which means that in the absence of fertility postponement, the TFR would have been higher. If the MAC had not increased, the TFR would have been higher than 2.0 in 1994, 1995, and 2010; it would have been no lower than 1.75 in any year in the 1990–2016 period. If the development in the MAC observed in 2017 were to follow a similar pattern in 2018, the estimated tempo-adjusted TFR for 2017 would be 1.65. Since the tempo-adjusted TFR has been higher than the observed TFR in each year since 1990, the tempo effect during this whole time period is clear. However, the tempo-adjusted fertility rate decreased in tandem with the observed TFR during 2010–17, which indicates that the decrease in the TFR in Finland since 2010 is not mainly attributable to changes in the timing of childbearing. The gap between the observed and tempo-adjusted TFRs still implies that the current observed period fertility levels are suppressed by continuing postponement of childbearing.

The mean age at first birth was 29.1 in 2017, which represents an increase of 2.6 years since 1990 (Figure 5(b)). The mean ages at second and third birth increased less, from 29.2 in 1990 to 31.1 in 2017 for second births, and from 31.8 in 1990 to 32.9 in 2017 for third births (Figure 5(c) and (d)). Since 2010, the TFR for first births has decreased from 0.78 to 0.61, for second births from 0.60 to 0.50, and for third births from 0.30 to 0.22. The tempo adjustments show the largest tempo effect for first births.

Cohort fertility of women born since 1974

Figure 6 shows the observed and forecasted completed CFRs for the 1940–87 birth cohorts in Finland. The latest observed CFR is for women born in 1973, since they reached age 44 in 2017, and thus have (almost) completed their fertility. These women had an average of 1.89 children, approximately the level that has been consistently observed over the last 30 years. However, all three forecasting methods suggest that there will be a substantial decrease in the completed CFRs of women who are currently in their childbearing years. According to all three methods, the average number of children born to each woman is likely to be lower than 1.7 for women currently aged 30 (1987 birth cohort) and lower than 1.75 for women in their early 30s (1985 birth cohort). For women in their late 30s (1980 birth cohort), cohort fertility is expected to reach 1.82, which is an all-time low in Finland based on currently available HFD data from the 1924 birth cohort onwards; the lowest value previously observed was 1.85 for the 1950 birth cohort. Even if fertility rates remained stable and did not decrease further at any age (see freeze

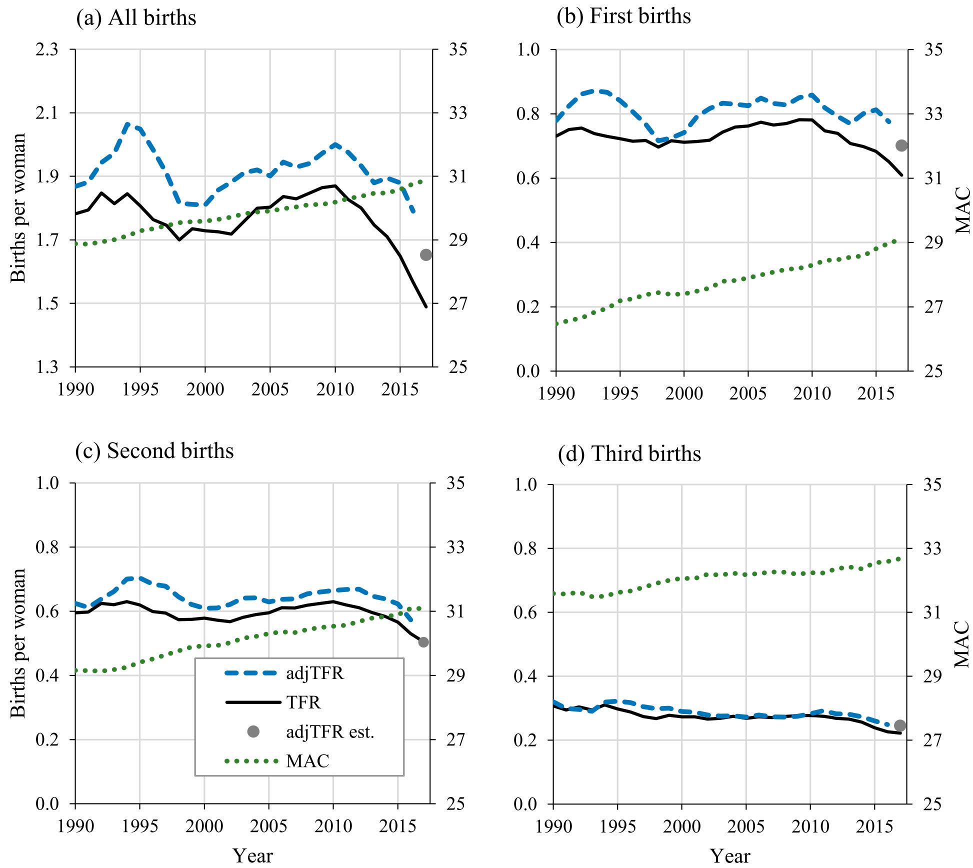

Figure 5 Observed and tempo-adjusted TFRs and mean age at childbearing (MAC) by birth order, calculated from unconditional fertility rates, Finland, 1990–2017

Note: adjTFR refers to the tempo-adjusted TFR and adjTFR est. refers to the crude estimate that replaces the lost value in 2017.

Source: As for Figure 4.

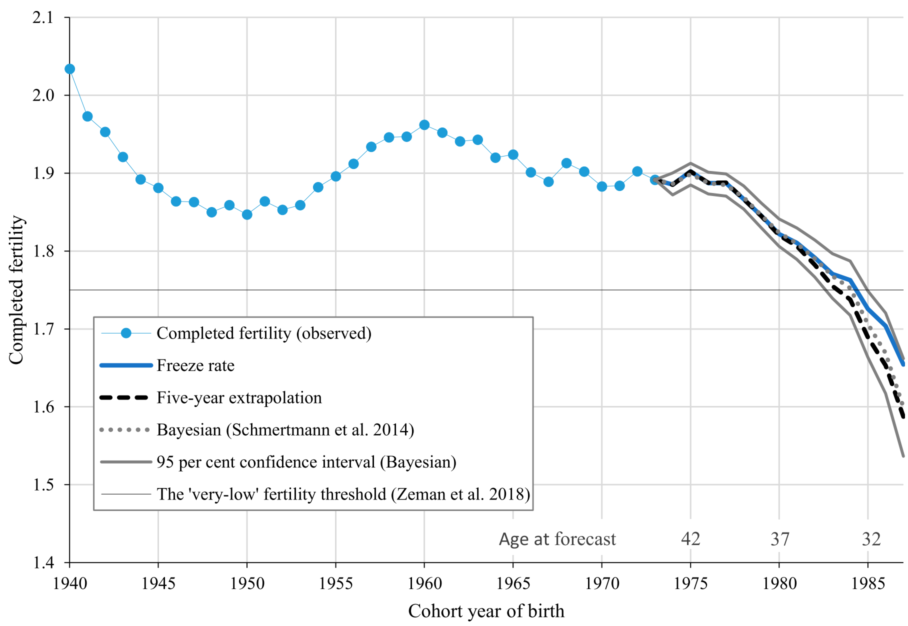

Figure 6 Observed completed fertility for cohorts born in 1940–73 and forecasted completed fertility for cohorts born in 1974–87, Finland

Source: As for Figure 4.

rate line), the CFR would approach 1.65 for the cohorts born in the late 1980s. This is, however, the most optimistic scenario, since both the five-year extrapolation method and the Bayesian method suggest that fertility declines will be larger. Both methods forecast completed fertility of 1.6 for the cohort born in 1987, for whom fertility has been observed up to age 30. The forecast uncertainty is, however, greater for cohorts with many as yet unobserved age-specific fertility rates. Taken together, the cohort fertility forecasts indicate that unless age-specific rates recover very rapidly, the cohort fertility rate in Finland will decrease dramatically in the near future.

Potential for recuperation of cohort fertility

How likely is it that fertility rates will recover fast enough to prevent a strong decrease in cohort fertility? While the probabilistic Bayesian forecast answers this question, the answer is ultimately based on a model, and it is unclear whether the model assumptions hold in the current context. To complement the model-based results, we use a non-parametric approach that does not impose any restrictions on the smoothness or shape of the fertility schedules. We calculate the changes in age-specific fertility rates in all HFD countries since 1975, and illustrate their hypothetical consequences for cohort fertility in Finland in Table 1. To keep the CFR of the 1985 cohort at 1.75, and using freeze rates as the baseline (forecasted CFR of 1.73, see panel (a)), a recuperation of 0.02 would be needed. In other words, the remaining fertility rates needed to make the CFR complete would have to increase by a total of 0.02 from the most recently observed age-specific fertility rates at ages 33–44. As this level of recuperation has occurred in more than half (53 per cent) of the trajectories in the HFD countries, it is not unlikely (panel (c)). However, the level of recuperation needed to keep the CFR at 1.75 increases for the younger cohorts. For the 1987 cohort, an increase of 0.10 is required (from the freeze rate forecast of 1.65); such an increase has been observed in only 16 per cent of the trajectories in the HFD countries.

Since strong recuperation at older ages has been a particular feature of the Nordic countries (Andersson et al. 2009), we additionally calculate the corresponding chances of keeping the CFR at 1.75 based on the patterns observed in the Nordic countries only (panel (c)). The likelihood of keeping the CFR at 1.75 would then be higher, at 75, 62, and 32 per cent, respectively, for the 1985, 1986, and 1987 cohorts. However, the likelihood that the CFR will remain at the latest observed level of 1.89 is extremely low, even given the recuperation patterns typical of the Nordic countries. Recuperations with strength levels in the 90th percentile would result in a CFR of around 1.80, but projections based on the most typical (median) recuperation patterns would result in a CFR below 1.75 for the youngest cohorts (panel (b)). Keeping the CFR at the level that has been observed in Finland in recent decades would therefore require a recuperation stronger than any that has previously occurred. Thus, while this non-parametric analysis shows that it is still possible for the CFR to remain above 1.75 for women born in the late 1980s, this is not what the current trend in Finland is indicating.

Discussion

Using aggregated data from the HFD, we analysed the rapid decline in period fertility by age and parity seen in recent years in Finland, and forecasted the ultimate cohort fertility for women currently of childbearing age. Our focus was on Finland because the period fertility decline that started in 2010 in many countries with relatively high fertility was particularly pronounced there. As reported previously, the long-term decrease in fertility rates among women below age 30 accelerated during the 2010–17 period, while the long-term increase among older women stagnated or even turned negative—as was the case among 30–39-year-olds. Our study shows that the greatest contributions to the decrease were produced by decreasing first-order births, particularly at ages 25–29. The period rates were depressed because the age at entering motherhood increased; they would have been higher in the absence of fertility postponement. The tempo-adjusted TFR did not, however, show increasing tempo effects, which implies that the decrease in total fertility cannot be explained by the accelerating postponement of childbearing. By updating existing Finnish cohort fertility forecasts (Myrskylä et al. 2013; Schmertmann et al. 2014) with the most recent data, we obtained results suggesting that among women born since the mid-1980s, completed fertility will fall sharply to levels below 1.75 unless fertility rates recover very rapidly. A turnaround in fertility at older ages would help to counterbalance decreases at younger ages, but a catch-up process that keeps cohort fertility stable is highly unlikely to occur. Continuously stable cohort fertility in

Table 1 (a) Summary of forecasted completed fertility (CFR) for cohorts born in 1975, 1980, and 1985–87 (parametric and model-based approaches); (b) Distribution of CFRs based on fertility changes observed in all HFD countries since 1975 (non-parametric approach); and (c) Likelihood of the CFR staying at 1.75 or higher based on past observed changes

	Cohorts				
Year of birth	1975	1980	1985	1986	1987
Age at forecast in 2017	42	37	32	31	30
(a) Forecasted CFR					
Freeze rate	1.90	1.82	1.73	1.70	1.65
Five-year extrapolation	1.90	1.82	1.70	1.65	1.59
Bayesian model	1.90	1.82	1.71	1.67	1.60
(b) Forecasted CFR based on empirical distribution of fertility changes in HFD countries since 1975					
99.5th percentile (99 per cent CI)	1.91	1.85	1.85	1.86	1.85
97.5th percentile (95 per cent CI)	1.90	1.84	1.83	1.84	1.81
90th percentile (80 per cent CI)	1.90	1.84	1.80	1.80	1.78
Median	1.90	1.83	1.75	1.74	1.70
10th percentile (80 per cent CI)	1.90	1.81	1.69	1.66	1.60
2.5th percentile (95 per cent CI)	1.90	1.80	1.64	1.60	1.53
0.5th percentile (99 per cent CI)	1.90	1.78	1.56	1.50	1.41
(c) Likelihood of CFR staying at 1.75 (percentage)					
Based on data from all HFD countries	–	–	53	43	16
Based on data from the Nordic countries[1]	–	–	75	62	32

[1]Denmark, Finland, Iceland, Norway, and Sweden.
Note: CI refers to confidence interval.
Source: Authors' calculations based on the Human Fertility Database.

future would require stronger recuperation than ever seen among older cohorts in high-income countries, and preliminary data for Finland beyond 2017 already display further decreasing period rates, that is, weak prospects for such a pattern (Official Statistics of Finland 2019). This points to an important shift in fertility patterns in Finland, as the country's cohort fertility declined only slightly among women born in the 1960s, and has generally been stable at around 1.90 over the last 30 years.

The multiple forecasting approaches used in this study produce consistent forecasts in terms of the direction of fertility development. However, the magnitude of the expected cohort fertility decline varies to some extent across the methods, as the central estimate for the 1987 cohort is around 1.60 from the two extrapolation-based methods, 1.65 from the freeze rate method, and 1.70 from the non-parametric approach. These differences in forecasted fertility are partially attributable to the inherent increase in uncertainty when forecasting with a longer time horizon, but they also reflect systematic differences in the modelling assumptions and their implications. For example, the recent change in the trend in fertility rates among women aged 30–39 from positive to negative suggests that different assumptions about future fertility developments are needed, since it is impossible to know whether this new trend will continue, plateau, or reverse, or when a deviation from this trend might occur. A key strength of our analysis is that the forecasting methods used in this study are based on different assumptions, and allow for each of these fertility developments to occur.

The five-year extrapolation method (Myrskylä et al. 2013) and the Bayesian method (Schmertmann et al. 2014) extrapolate past trends into the future. As recent trends have been negative among all age groups except for women aged 40+, these methods produce the lowest CFRs, and perform well when a continuous trend is uninterrupted during a period of time. If the trend were to plateau, as the freeze rate method assumes, the forecasted CFRs would be slightly higher. These three methods still consistently produce forecasted CFRs substantially below 1.75 for women born in 1987. However, the non-parametric approach suggests that there is a one in six to one in three chance of the CFR staying at 1.75 or higher for the 1987 cohort (Table 1). This approach does not make assumptions about future trends, and instead shows the most likely recuperation paths, based on recorded fertility histories in high-income countries over the past four decades. As the main feature of the fertility histories has been an ongoing increase in fertility at higher ages, this non-parametric method samples possible recuperation histories from a data set dominated by patterns in which fertility rates at older ages increase.

Consequently, this method produces the highest forecasted CFR for the 1987 birth cohort (observed up to age 30), with a median of 1.70. Importantly, however, the lack of assumptions regarding trends or age schedules in this non-parametric approach implies that some of the forecasted recuperation trajectories may be implausible in terms of the age pattern or time trend. Moreover, while our forecasts use data up to 2017, recent data indicate that fertility has continued to decline since 2017 (Official Statistics of Finland 2019). This suggests that our estimate of a one in six to one in three likelihood of the CFR remaining at 1.75 or above is likely to be an upper bound of the true likelihood of such a fertility recuperation occurring.

These findings challenge the view of Finland as part of the common Nordic fertility regime that exhibits a combination of high and stable fertility together with high support for working mothers and consequently high labour force participation and childcare enrolment. Instead, the results place Finland among the group of countries with very low fertility rates—currently found in Central, Eastern, and Southern Europe and in East Asia—that often lack support for working mothers. A cohort fertility decline in Finland would be an interesting development more generally, given the widespread assumption that the Nordic countries have maintained close to replacement-level fertility through generous social policies promoting work–family reconciliation. A common feature of childbearing behaviour in these countries has been a strong recuperation of postponed births at older ages, which has caused cohort fertility to remain stable even as the age at entry into motherhood increased (Andersson et al. 2009). This new trend of stagnating or decreasing childbearing intensity among Finnish women in their 30s implies that this pattern may be changing in Finland. The evidence suggests that women currently of higher childbearing ages are not catching up on births to the same extent as previous generations. Based on several cohort forecast approaches applied in this study, a catch-up that would keep cohort fertility stable is highly unlikely to occur. However, given the recent history of recuperation paths observed in the Nordic countries, there was, as of 2017, still a reasonable possibility that completed fertility would not fall below 1.75 if fertility at older ages recovered substantially. The crucial question is whether a strong recuperation typical of those in the Nordic countries can still be expected in Finland.

Given that Finland is considered an advanced country in terms of gender equality (World Bank 2012), the current findings do not necessarily support the assumption that there is a positive association between fertility and gender equality. Demographic theories suggest that fertility levels will increase if the ‘second shift’ experienced by working women is alleviated by men becoming more involved in the family and by stronger institutional support (Anderson and Kohler 2015; Esping-Andersen and Billari 2015; Goldscheider et al. 2015). In a recent study, no evidence was found that fertility would increase in societies with the most advanced levels of gender equality (Kolk 2019). Notably, women in the Nordic countries still continue to perform more unpaid work than men, including more childcare and other housework (Hook 2006; Prince Cooke and Baxter 2010), and previous individual-level studies have noted that high fertility is concentrated among women who stay at home to care for their children for long spells, or who work in more family-friendly jobs in the public sector (Rønsen and Sundström 2002; Duvander et al. 2010; Miettinen et al. 2011). Particularly in Finland, the responsibility for rearing small children lies heavily on the mother (Nordic Social Statistical Committee 2017; Hudde 2018; OECD 2019). If cohort fertility in Finland were to fall below 1.75, as the conventional forecasts predict, it would become similar to the levels currently observed among the ‘late developers’, that is, countries such as those in Southern and Eastern Europe, where the fertility transition occurred later and gender equality is less advanced (Anderson and Kohler 2015).

In comparison to other countries, levels of ultimate childlessness in Finland are high (Neyer et al. 2006; Kreyenfeld and Konietzka 2017). As we find in this study, the decline in period fertility is mainly attributable to decreasing first birth rates, although rates of higher-order births, particularly second births, have decreased as well. This means that larger shares of young women are currently childless than was the case only a few years ago: less than half of all Finnish women currently aged 30 have entered motherhood. Without an exceptionally strong recuperation in first births at older ages, ultimate childlessness will increase further in Finland. Indeed, ultimate childlessness may become a strong driver of cohort fertility decline, given the increasing trends in ultimate childlessness observed in many countries among women born from the 1940s onwards (Sobotka 2017; Zeman et al. 2018). In the Nordic context, however, Finland might become even more of an outlier, since in Denmark, Norway, and Sweden increases in ultimate childlessness have plateaued among the most recent cohorts (Sobotka 2017; Jalovaara et al. 2019).

It is unclear what underlying factors or socio-economic determinants are driving this fertility decline in Finland. Previous studies from the Nordic countries have shown that fertility rates are positively related to economic cycles (Andersson 2000; Kravdal 2002). More generally, Matysiak et al. (2018) showed that the Great Recession in 2008–14 negatively affected fertility rates in Europe, and argued that not only the timing but the quantum of fertility may have been affected. In Finland, fertility rates declined more during the recent Great Recession than during the recession in the early 1990s (Hiilamo 2017). The negative association between unemployment and first childbearing is stronger for men than for women in Finland (Miettinen and Jalovaara 2019), and this association has become stronger since the Great Recession, at least for women (Comolli 2019). As period fertility rates are still declining despite the fact that the economic recession ended years ago, Comolli et al. (2019) have argued that the recession may have affected people's perceptions of welfare uncertainty, with implications for childbearing decisions after an economic crisis.

However, the most remarkable change in recent years seems to be that Finns simply want fewer children and more commonly prefer to remain childless. The annual Family Barometer survey in Finland found that the share of women with no children or only one child who did not intend a(nother) child had increased in all age groups in the last decade: from below 10 to almost 30 per cent in the 25–29 age group, from almost 15 to 35 per cent in the 30–34 age group, and from almost 40 to over 60 per cent among those aged 35–39 (Berg 2018). Additionally, the desire to pursue interesting life goals other than parenting is now becoming the most important reason, ahead of both economic factors and the lack of a partner, to postpone childbearing (Miettinen 2015). Consequently, the recent strong period fertility decline may reflect changes in family values in Finland. This assumption would not be at odds with our finding of a sharp decrease in first births among women aged 25–29. Moreover, it would make the recuperation of fertility at older ages even more unlikely in the years to come.

The Nordic countries have experienced relatively high and stable cohort fertility in recent decades, despite the ongoing process of fertility postponement. Using a variety of analytical tools, including several cohort fertility forecasts, this study shows that the all-time low period fertility currently observed in Finland is not a consequence of accelerating fertility postponement, but is most likely a reflection of decreasing fertility quantum. Finnish women who were born in the mid-1980s, and are thus currently of higher childbearing ages, are likely to end up having fewer children on average than previous generations of women. Our results therefore suggest that Finland may not conform to the idea of a Nordic fertility regime. Recent fertility declines in other Nordic countries tentatively point to developments similar to those in Finland, albeit at fertility levels that are still higher. If, however, the other Nordic countries follow Finland, the concept of the Nordic model of fertility may require updating. This study casts doubt on the assumption that Finland will continue to be seen as a Nordic country characterized by relatively high and stable fertility, and thus suggests that even having comparatively strong institutional support for gender equality may not hinder declines in fertility.

Notes and acknowledgements

1 Please direct all correspondence to Julia Hellstrand, Max Planck Institute for Demographic Research, Konrad-Zuse-Straße 1, 18057 Rostock, Germany; or by E-mail: hellstrand@demogr.mpg.de

2 The authors would like to acknowledge Aiva Jasilioniene for providing them with the most recent HFD data updates, Christian Dudel for help with the methods, and two anonymous reviewers whose comments have greatly improved this paper.

3 This work was supported by H2020 European Research Council [grant number 336475, Costs and Gains to Fertility Postponement].

References

Andersson, G. 2000. The impact of labour-force participation on childbearing behaviour: Pro-cyclical fertility in Sweden during the 1980s and the 1990s, *European Journal of Population* 16(4): 293–333. doi:10.1023/A:1006454909642

Andersson, G. 2004. Childbearing developments in Denmark, Norway, and Sweden from the 1970s to the 1990s: A comparison, *Demographic Research* S3: 155–176.

Anderson, T., and H.-P. Kohler. 2015. Low fertility, socioeconomic development, and gender equity, *Population and Development Review* 41(3): 381–407. doi:10.1111/j.1728-4457.2015.00065.x

Andersson, Gunnar, Marit Rønsen, Lisbeth B. Knudsen, Trude Lappegård, Gerda Neyer, Kari Skrede, Kathrin

Teschner, and Andres Vikat. 2009. Cohort fertility patterns in the Nordic countries, *Demographic Research* 20(14): 313–352.

Andreev, E. M., and V. M. Shkolnikov. 2012. *An Excel Spreadsheet for the Decomposition of a Difference Between Two Values of an Aggregate Demographic Measure by Stepwise Replacement Running From Young to Old Ages, MPIDR Technical Report TR-2012-002*. Rostock: Max Planck Institute for Demographic Research.

Andreev, E. M., V. M. Shkolnikov, and A. Begun. 2002. Algorithm for decomposition of differences between aggregate demographic measures and its application to life expectancies, healthy life expectancies, parity-progression ratios and total fertility rates, *Demographic Research* 7(14): 499–522.

Berg, V. 2018. *Touko 2018 Tietovuoto: Suomalaiset haluavat nykyään vähemmän lapsia kuin ennen* [Finnish people currently desire less children than before]. Available: http://www.vaestoliitto.fi/tieto_ja_tutkimus/vaestontutkimuslaitos/tietovuodot/touko-2018-tietovuoto/

Bohk-Ewald, C., P. Li, and M. Myrskylä. 2018. Forecast accuracy hardly improves with method complexity when completing cohort fertility, *Proceedings of the National Academy of Sciences* 115(37): 9187–9192. doi:10.1073/pnas.1722364115

Bongaarts, J., and G. Feeney. 1998. On the quantum and tempo of fertility, *Population and Development Review 24*(2): 271–291. doi:10.2307/2807974

Comolli, C. L. 2018. Finnish fertility: Pro-or counter-cyclical?, *Research on Finnish Society* 11: 58–64.

Comolli, C. 2019. *Couples' Transition to Parenthood in Finland: A Tale of Two Recessions.* Stockholm: Stockholm Research Reports in Demography. Preprint. https://doi.org/10.17045/sthlmuni.7611455.v1

Comolli, Chiara, Gerda Neyer, Gunnar Andersson, Lars Dommermuth, Peter Fallesen, Marika Jalovaara, Ari Klængur Jónsson, Martin Kolk, and Trude Lappegård. 2019. Beyond the economic Gaze: Childbearing During and After Recessions in the Nordic Countries, *Stockholm Research Reports in Demography* (16). doi:10.17045/sthlmuni.8089028.v1

Denton, F. T., C. H. Feaver, and B. G. Spencer. 2005. Time series analysis and stochastic forecasting: An econometric study of mortality and life expectancy, *Journal of Population Economics* 18: 203–227.

Dudel, C. 2015. Vorausberechnung des Pflegepotentials von erwachsenen Kindern für ihre pflegebedürftigen Eltern, *Sozialer Fortschritt* 64(1-2): 14–26. doi:10.3790/sfo.64.1-2.14

Duvander, A.-Z., T. Lappegård, and G. Andersson. 2010. Family policy and fertility: fathers' and mothers' use of parental leave and continued childbearing in Norway and Sweden, *Journal of European Social Policy* 20(1): 45–57. doi:10.1177/0958928709352541

Ellingsæter, A. L., and A. Leira. 2006. *Politicising Parenthood in Scandinavia: Gender Relations in Welfare States.* Bristol: Policy Press, Bristol University Press.

Esping-Andersen, G., and F. C. Billari. 2015. Re-Theorizing Family Demographics, *Population and Development Review* 41(1): 1–31. doi:10.1111/j.1728-4457.2015.00024.x

Eurostat. 2019. Births and fertility. Available: https://ec.europa.eu/eurostat/documents/2995521/9648811/3-1203 2019-AP-EN.pdf/412879ef-3993-44f5-8276-38b482c766d8

Frejka, T. 2008. Overview Chapter 2: Parity distribution and completed family size in Europe: Incipient decline of the two-child family model? *Demographic Research* 19(4): 47–72. doi:10.4054/DemRes.2008.19.4

Frejka, T. 2017. The fertility transition revisited: A cohort perspective, *Comparative Population Studies* 42(2017): 89–116.

Goldscheider, F., E. Bernhardt, and T. Lappegård. 2015. The gender revolution: A framework for understanding changing family and demographic behavior, *Population and Development Review* 41(2): 207–239. doi:10.1111/j.1728-4457.2015.00045.x

Goldstein, J. R., T. Sobotka, and A. Jasilioniene. 2009. The end of "lowest-low" fertility? *Population and Development Review* 35(4): 663–699. doi:10.1111/j.1728-4457.2009.00304.x

Hiilamo, H. 2017. Fertility response to economic recessions in Finland 1991–2015, *Finnish Yearbook of Population Research* 52: 15–28.

Hook, J. L. 2006. Care in context: Men's unpaid work in 20 countries, 1965–2003, *American Sociological Review* 71 (4): 639–660. doi:10.1177/000312240607100406

Hudde, A. 2018. Societal agreement on gender role attitudes and childlessness in 38 countries, *European Journal of Population* 34(5): 745–767.

Jalovaara, M. A., and E. Fasang. 2017. From never partnered to serial cohabitors: Union trajectories to childlessness, *Demographic Research* 36(55): 1703–1720.

Jalovaara, M., G. Neyer, G. Andersson, J. Dahlberg, L. Dommermuth, P. Fallesen, and T. Lappegård. 2019. Education, gender, and cohort fertility in the Nordic countries, *European Journal of Population* 35(3): 563–586. doi:10.1007/s10680-018-9492-2

Jasilioniene (01 November 2018).

Jónsson, A. K. 2017. Childbearing trends in Iceland, 1982–2013: Fertility timing, quantum, and gender preferences for children in a Nordic context, *Demographic Research* 37(7): 147–188.

Keyfitz, N. 1985. A probability representation of future population. *Zeitschrift für Bevölkerungswissenschaft* 11: 179–191.

Keyfitz, N. 1989. *Measuring in Advance the Accuracy of Population Forecasts*, *Working paper, IIASA: WP-89-072*.

Kohler, H.-P., F. C. Billari, and J. A. Ortega. 2002. The emergence of lowest-low fertility in Europe during the 1990s, *Population and Development Review* 28(4): 641–680. doi:10.1111/j.1728-4457.2002.00641.x

Kolk, M. 2019. Weak support for a U-shaped pattern between societal gender equality and fertility when comparing societies across time, *Demographic Research* 40(2): 27–48.

Kravdal, Ø. 2002. The impact of individual and aggregate unemployment on fertility in Norway, *Demographic Research* 6: 263–294.

Kreyenfeld, M., and D. Konietzka. 2017. *Childlessness in Europe: Contexts, Causes, and Consequences*. Dordrecht: Springer.

Matysiak, A., T. Sobotka, and D. Vignoli. 2018. *The Great Recession and Fertility in Europe: A Sub-National Analysis*, *Vienna Institute of Demography, Working Papers*.

Merz, E.-M., and A. C. Liefbroer. 2018. Cross-national differences in the association between educational attainment and completed fertility. Do welfare regimes matter? *Vienna Yearbook of Population Research* 1: 95–120.

Miettinen, A. 2010. Voluntary or involuntary childlessness? Socio-demographic factors and childlessness intentions among childless Finnish men and women aged 25–44, *Finnish Yearbook of Population Research* 45: 5–24.

Miettinen, A. 2015. *Miksi syntyvyys laskee? Suomalaisten lastensaantiin liittyviä toiveita ja odotuksia. Perhebarometri 2015* [Why do birth rates decrease? The childbearing desires and expectations of Finnish people], Väestöntutkimuslaitos, Katsauksia E49. Helsinki: Väestöliitto.

Miettinen, A., S. Gietel-Basten, and A. Rotkirch. 2011. Gender equality and fertility intentions revisited: Evidence from Finland, *Demographic Research* 24(20): 469–496.

Miettinen, A., and M. Jalovaara. 2019. Unemployment delays first birth but not for all. Life stage and educational differences in the effects of employment uncertainty on first births, *Advances in Life Course Research* doi:10.1016/j.alcr.2019.100320

Myrskylä, M., J. R. Goldstein, and Y. A. Cheng. 2013. New cohort fertility forecasts for the developed world: Rises, falls, and reversals, *Population and Development Review* 39(1): 31–56. doi:10.1111/j.1728-4457.2013.00572.x

Neyer, G., G. Andersson, J. Hoem, M. Rønsen, and A. Vikat. 2006. *Fertilität, Familiengründung und Familienerweiterung in Den Nordischen Ländern*, *Max Planck Institute for Demographic Research, Rostock, Germany. (MPIDR Working Paper WP 2006-022)*.

Nordic Social Statistical Committee (NOSOSOCO). 2017. *Social Protection in the Nordic Countries: Scope, Expenditure and Financing 2015/2016*. Available: http://nowbase.org/publications/social-protection-nordiccountries

OECD. 2019. *OECD family database*. Available: http://www.oecd.org/social/family/database.htm

Official Statistics of Finland (OSF). 2010. Population structure [e-publication]. Available: http://www.stat.fi/til/vaerak/2010/01/vaerak_2010_01_2011-09-30_tau_005_en.html

Official Statistics of Finland (OSF). 2015. Births [e-publication]. Available: https://www.stat.fi/til/synt/2015/02/synt_2015_02_2016-12-08_tie_001_en.html

Official Statistics of Finland (OSF). 2019. Births [e-publication]. Available: http://www.tilastokeskus.fi/til/synt/2018/synt_2018_2019-04-26_tie_001_en.html

Prince Cooke, L., and J. Baxter. 2010. Families' in international context: Comparing institutional effects across western societies, *Journal of Marriage and Family* 72(3): 516–536. doi:10.1111/j.1741-3737.2010.00716.x

Rindfuss, R. R., M. K. Choe, and S. R. Brauner-Otto. 2016. The emergence of two distinct fertility regimes in economically advanced countries, *Population Research and Policy Review* 35(3): 287–304.

Roustaei, Z., S. Raisanen, M. Gissler, and S. Heinonen. 2019. Fertility rates and the postponement of first births: A descriptive study with Finnish population data, *BMJ OPEN* 9:e026336. doi:10.1136/bmjopen-2018-026336

Rønsen, M., and K. Skrede. 2010. Can public policies sustain fertility in the Nordic countries?: Lessons from the past and questions for the future, *Demographic Research* 22(13): 321–346.

Rønsen, M., and M. Sundström. 2002. Family policy and after-birth employment among new mothers – a comparison of Finland, Norway and Sweden, *European Journal of Population* 18(2): 121–152. doi:10.1023/a:1015532305179

Saarela, J., and V, Skirbekk. 2019. Childlessness and union histories: evidence from Finnish population register data, *Journal of Biosocial Science* 1–19. doi:10.1017/S0021932019000257

Schmertmann, C., E. Zagheni, J. R. Goldstein, and M. Myrskylä. 2014. Bayesian forecasting of cohort fertility, *Journal of the American Statistical Association* 109(506): 500–513. doi:10.1080/01621459.2014.881738

Sobotka, T. 2017. Childlessness in Europe: Reconstructing long-term trends Among women born in 1900–1972, in M. Kreyenfeld and D. Konietzka (eds.), *Childlessness in Europe: Contexts, Causes, and Consequences*. Cham: Springer International Publishing, pp. 17–53.

World Bank. 2012. *World Development Report 2012: Gender Equality and Development: Main Report (English)*. Available: World development report.

Washington, DC: World Bank Group: http://documents.worldbank.org/curated/en/492221468136792185/Main-report

Zeman, K., E. Beaujouan, Z. Brzozowska, and T. Sobotka. 2018. Cohort fertility decline in low fertility countries: Decomposition using parity progression ratios, *Demographic Research* 38(25): 651–690.

Appendix 1: Tempo-adjusted TFR

The tempo-adjusted total fertility rate (*adjTFR*) by Bongaarts and Feeney (1998) is the sum of order-specific adjusted fertility rates, which are calculated as

$$adjTFR_i(t) = \frac{TFR_i(t)}{1 - r_i(t)}$$

where i represents birth order and t represents year. The adjustment factor $r_i(t)$ is estimated by

$$r_i(t) = \frac{MAC_i(t+1) - MAC_i(t-1)}{2}$$

where $MAC_i(t)$ is the mean age of childbearing by birth order i at year t. We consider birth orders 1, 2, 3, 4, and 5 + . Due to the large annual fluctuations in the adjusted rates, a smoothed version of the *adjTFR* is calculated using a three-year moving average of the adjustment factors by each birth order to increase stability in the time series.

Since the latest year's observation is lost in the Bongaarts–Feeney adjustment, a crude estimate is calculated to replace the lost value. We use the adjustment factor

$$r_i(t)' = MAC_i(t) - MAC_i(t-1)$$

for the latest year's observation, following Goldstein et al. (2009), but emphasize that the crude estimate should be read with caution. The crude estimate assumes that the development in the mean age of childbearing will follow roughly the same trend this year as that observed in the previous year—which is, however, not necessarily true.

Appendix 2: Bayesian forecasting of cohort fertility

The Bayesian forecasting method (Schmertmann et al. 2014) automatically includes uncertainty estimates, and no explicit choice between the freeze rate approach and the five-year extrapolation approach needs to be made in the Bayesian framework. The Bayesian cohort fertility forecasting method uses two separate non-overlapping subsets formed from the HFD: contemporary data and historical data. The contemporary data consist of ten complete cohort schedules for Finnish cohorts born in 1964–73 and 30 incomplete schedules for Finnish cohorts born in 1974–2003, and the surface of the incomplete schedules is to be forecasted. The historical data (Table A2) consist of $N = 648$ complete cohort schedules for cohorts born in high-income countries between 1900 and 1960, and is used as a priori information about typical shapes of the cohort fertility schedules and time-series trends in fertility rates across countries.

The Bayesian model could be applied using either the prior shape and the time series, or the prior time series only. If the cohort fertility schedule of interest is not well represented in the historical data, a model with prior time series only may be preferable. Our results are based on the prior shape and the time series, but a prior distribution with time-series penalties only did not substantially change the results.

Table A2 The historical data set used to build the prior information in the Bayesian forecasting model

Country	n	Birth cohorts
Austria	25	1936–60
Bulgaria	29	1932–60
Canada	55	1906–60
Czechia	26	1935–60
Estonia	17	1944–60
Finland	37	1924–60
France	30	1931–60
Germany	20	1941–60
West Germany	20	1941–60
East Germany	20	1941–60
Hungary	26	1935–60
Lithuania	17	1944–60
Netherlands	26	1935–60
Portugal	36	1925–60
Russia	17	1944–60
Slovakia	26	1935–60
Sweden	61	1900–60
Switzerland	44	1917–60
Great Britain	2	1959–60
England and Wales	38	1923–60
Scotland	31	1930–60
Northern Ireland	2	1959–60
USA	43	1918–60

Source: Human Fertility Database: Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at www.humanfertility.org (accessed 28 November 2019).